Are Increases in Thunderstorm Activity in Southeast China Related to Air Pollution?

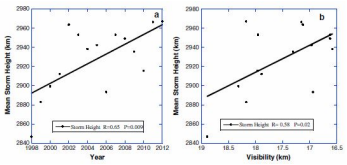
Research Highlight

Pollution aerosols are thought to have an invigorative effect on convective clouds by suppressing warm precipitation in moist and convectively unstable environments. As clouds develop to above the freezing level, mixed-phase clouds containing ice and supercooled water can grow further more readily and induce cloud electrification and thunderstorms during summertime. In southeastern China, the summer monsoon brings in abundant water vapor from the Pacific Ocean which helps intensify convective phenomena like thunderstorms and lightning. Aerosol loading in this region is very high as a result of the rapid development of the region's economy and population. The goal of this study is to investigate long-term trends in thunderstorm and lightning activities in a moist summertime environment containing high aerosol concentrations using satellite data and ground observations.

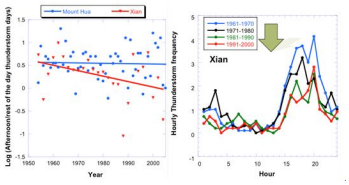
An analysis of 15 years (1998–2012) of lightning and precipitation data retrieved from the Tropical Rainfall Measurement Mission satellite and surface measurements (1990–2012) of visibility, a proxy for the local aerosol burden, made at 70 plain stations and 4 mountain stations show a number of trends that paint a picture of the possible role of aerosols in intensifying thunderstorms. Overall, thunderstorm and lightning activities have increased over time in southeast China while visibility has decreased over the past decades. The daily number of flashes (a measure of convective strength) and the number of flashes per rainy pixel are inversely correlated with visibility. Storm heights, which indicate the highest altitude large droplets or particles can reach, are also inversely correlated with visibility. The increases in thunderstorm days and storm height suggest that the intensification of convection is enhanced not only in frequency but also in intensity.

One way to isolate the influence of aerosols from dynamics is to study the contrast in thunderstorm activity between mountains and nearby plain regions because they are governed by the same large-scale synoptic systems but have distinct aerosol loadings. The plain-to-mountain ratio of thunderstorm days increased substantially during the period of 1990–2012. At the same time, the number of thunderstorm days for the mountain stations has a much weaker trend, suggesting that the increase in thunderstorm activities is much more significant at plain stations than at mountain stations. The ratio of cloudy days had no trend over the years. This suggests that the general synoptic conditions favorable for the development of thunderstorms remained almost the same over the years. The sharper increase in thunderstorm occurrence over the plain region, compared to the mountain region, may thus not be explained by synoptic reasons but are more likely due to the action of aerosols. The distinct trends seen between plain and mountain stations may originate from large differences in aerosol concentration between the plain and mountain regions. The accumulation of pollution aerosols in the plain region likely invigorates thunderstorms, whereas a lesser, or no, impact on intense convection is found over high-altitude regions. Another piece of evidence that supports the idea that changes in the atmospheric environment cannot explain the increasing trend in thunderstorm activities in the plain region is that atmospheric moisture has decreased more over plain stations than over mountain stations.

It is worth noting that an opposite trend was found in another of our studies focused on central China where black carbon aerosols dominate. Thunderstorm activities have been persistently decreasing, which suggests that different types of aerosols can affect thunderstorm activities differently. In this case, the stabilization induced by absorbing aerosol tends to suppress convection and the development of thunderstorms.



Left: Inter-annual variation in mean storm heights over Southeast China where pollution dominated by sulfate aerosols has increased due to intensive industrial activities. Right: Mean storm height as a function of visibility.



Left: Long-term trend in the number of thunder days from the 1960s to the 2000s at Mountain Hua and Xian, a nearby mega-city on the Guanzhong Plain. Right: Thunderstorm frequency according to hour of the day at Xian.

Reference(s)

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Cloud-Aerosol-Precipitation Interactions